Prediction of Liquid Metal Alloy Radiant Properties from Measurements of the Hall Coefficient and the Direct Current Resistivity*

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Presented to:
1995 National Heat Transfer Conference
Portland, Oregon
August 5-9, 1995

The thermal radiative properties of high temperature solid and liquid metal alloys are particularly useful to research and development efforts in laser cladding and machining, electron beam welding and laser isotope separation but the cost, complexity, and difficulty of measuring these properties has forced the use of crude estimates from the Hagen-Rubens relation, the Drude relations, or extrapolation from low temperature or otherwise flawed data (e.g., oxidized). We have found that published values for the Hall coefficient and the electrical resistivity of liquid metal alloys may provide useful estimates of the reflectance and emittance of some groups of binary liquid metal and high temperature solid alloys.

The estimation method computes the Drude free electron parameters, and thence the optical constants and the radiant properties from the dependence of the Hall coefficient and direct current resistivity on alloy composition (the Hall coefficient gives the free electron density and the resistivity gives the collision frequency). We find that predictions of the radiant properties of molten cerium-copper alloy, which use the measured variations in the Hall coefficient and resistivity (both highly nonlinear) as a function of alloy fraction (rather than linear conbinations of the values of the pure elements) yields a good comparison to published measurements of the variation of the normal spectral emittance (a different but also nonlinear function) of cerium-copper alloy at the single wavelength available for comparison, 0.645 μm.

The success of the approach in the visible range is particularly notable because one expects a Drude based approach to improve with increasing wavelength from the visible into the infrared. Unfortunately, no other wavelengths or binary alloy systems have been identified for comparison. However, several binary alloy systems involving rare earths combined with highly conducting metals (e.g. copper and aluminum) have similar qualitative dependence of the Hall coefficient and resistivity on composition in the liquid state. Details of the estimation method, the comparison between the calculation and the measured emittance, and a discussion of what groups of elements may also provide agreement is given.

*This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.